Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

JOHN F. KELLY, EDITOR

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Volume X. APRIL, 1933 Number IV

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Published Monthly by

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Locomotives For Shifting Purposes In Industrial Plants

By D. M. PETTY
Superintendent Service Division, Bethlehem Steel Company, Bethlehem, Pa.

Presented before the Philadelphia District Section of the A. I. & S. E. E., March, 1933.

To cover this subject in all its phases would require more time than is at our disposal. We will therefore confine this discussion to a brief review of the general mechanics of the problem, a description of the various types of locomotives available, with emphasis on some of the more modern ones, and some of the economic phases of the subject.

Tractors and similar locomotives which do not require tracks, as well as very small locomotives, will be considered as without the scope of this discussion.

D. M. PETTY

In studying any problem involving forces, acceleration, weights, etc., it is well to ever have before us the fundamental mathematics involved; therefore the following review will not be out of place.

1. **Acceleration** is the rate of change of velocity and is expressed:—

$$\text{acceleration equals } \frac{\text{Force}}{\text{Mass}}$$

that is, acceleration varies directly as the force and inversely as the mass.

2. **Velocity** is the rate of motion and can be expressed:—

$$\text{velocity equals acceleration} \times \text{time.}$$

$$\text{equals } \frac{\text{Force}}{\text{Mass}} \times \text{time.}$$

A given velocity can be reached in a short time if the force is great or the mass small. The resistance of a body against acceleration is frequently called inertia, and the product of the mass and velocity is frequently called momentum, or quantity of motion.

3. **Work,** mechanically, is overcoming resistance and can be written:—

$$\text{work equals average force} \times \text{distance.}$$

$$\text{equals average force} \times \text{average velocity} \times \text{time.}$$

Rate of work or mechanical power equals average force x average velocity.

The common unit of rate of work is horse-power and equals 550 foot lbs. per second, that is lifting 550 lbs. one foot in one second, or moving 550 feet against a resistance of one lb. in one second.

4. **Energy** is the capacity of an agent for doing work and in the case of a moving body is called Kinetic Energy.

$$\text{Kinetic energy equals one-half Mass} \times (\text{Velocity})^2$$

$$\text{equals one-half Mass} \times \left(\frac{\text{Force}}{\text{Mass}} \times \text{time}\right)^2$$

A body may be able to do work by virtue of its position such as water falling over a dam, or steam being released from a boiler due to its temperature and pressure. This is called Potential Energy.

These principles have been generalized into a law called the "Conservation of Energy" which, at least, implies that the total energy of the universe, that is the sum of the Kinetic and Potential Energies, remains constant. It was made the fundamental theorem of classical physical science. Modern atomic theories, however, throw some doubt on the validity of this general statement but so far as the problems of acceleration are concerned, the old law still holds.

In applying the above formulae, the proper units must be used. For the purpose of this discussion, the acceleration, due to gravity is assumed to be 32 feet per sec. per sec. The unit of weight is the pound, and the unit of time, the second.

Omitting all friction, a force of 25,000 lbs. can accelerate a weight of 400,000 lbs. in a horizontal direction at the rate of 2 feet per second, per second.

$$\text{acceleration equals } \frac{\text{Force}}{\text{Mass}} \text{ equals } \frac{25{,}000}{\frac{400{,}000}{32}} \text{ lbs. or 2 ft. per second, per second.}$$

$$\text{velocity equals acceleration} \times \text{time.}$$

$$\text{at end of 2 sec., vel. equals 2 ft. per sec. per sec.} \times 2 \text{ sec.}$$

$$\text{equals 4 ft. per sec.}$$

$$\text{h.p. or rate of doing work equals average vel.} \times \text{force} \times \text{a constant}$$

$$\text{equals } \frac{4}{2} \times 25{,}000 \times \frac{1}{550}$$

$$\text{Equals 91 h.p.}$$

$$\text{energy consumed equals Av. Vel.} \times \text{force} \times \text{time.}$$

$$\text{equals } \frac{4}{2} \times 25{,}000 \times 2.$$

$$\text{equals 100,000 ft. lb.}$$

$$\text{equals 182 h.p. seconds}$$

$$\text{or energy equals } \tfrac{1}{2}\, MV^2$$

$$\text{equals } \tfrac{1}{2} \times \frac{400{,}000}{32} \times (4)^2$$

$$\text{equals 100,000 ft. lb.}$$

$$\text{equals 182 h.p. seconds}$$

To accelerate to 22 ft. per sec. or 15 miles per hr.

Velocity equals acceleration times time

$$\text{time equals } \frac{\text{Vel.}}{\text{acceleration}} \text{ equals } \frac{22 \text{ ft. per sec.}}{2 \text{ ft. per sec. per sec.}}$$

equals 11 seconds.

$$\text{h.p. equals } \frac{22}{2} \times 25{,}000 \times \frac{1}{550}$$

equals 500 h.p.

In referring to locomotives, the ability to exert a certain pull or push is usually called Tractive Force and is measured in pounds.

It is limited **first** by the weight on the driving wheels and the coefficient of friction between the wheels and the rail usually called factor of adhesion. Under most favorable conditions, this is considered as 30% of weight on the driving wheels.

and **second** by the size of the engine and the gear ratio between it and the driving wheels.

A 50-ton locomotive can have a tractive force of 30,000 lbs. If it exerts this force at an average speed of one foot per sec. or .68 miles per hour, the h.p. required is 54.5

5 ft. per sec. or 3.4 mi. per hr. h.p. required is 272.5

10 ft. per sec. or 6.8 mi. per hr., h.p. required is 545.

The designer must decide what size engine is to be installed and then work out a gear ratio that will permit the engine to slip its wheels at standstill or even when running at some low rate of speed.

An adjustable gear ratio makes the engine much more flexible and this is one reason why the electric locomotive has proven so valuable, the generator and motors by voltage and connection control making an ideal adjustable gear ratio.

In railroad work, it has become common practice to reduce the formulae to a per ton unit since weight of locomotives as well as trains, are usually given in tons. A train as well as a locomotive has two kinds of inertia to overcome: First, the straight line longitudinal; second, the rotative. The latter, except in cases of very high speeds, is a small percentage of the total; an average quite usually accepted is that the inertia of the wheels is about 5% of the total inertia.

The curves on Fig. 1 show force in pounds per ton of total weight required to accelerate a train from rest.

These curves are not exact and are based on the formula: force equals $95.6 \frac{\text{Velocity (Mi. per Hr.)}}{\text{Time (in sec.)}}$

With the above curve, the h.p. required can be calculated on the basis of the final velocity, as

$$\text{h.p. equals } \frac{\text{average force in lbs. x aver. vel. in ft. per sec.}}{550.}$$

$$\text{equals } \frac{\text{force in lbs. per ton x weight of train in tons x Vel. (in mi. per hr.)}}{550 \times .682}$$

In order that a locomotive can accelerate a train from rest to some given speed, it must first be able to exert enough torque to overcome breakaway friction and running friction, the remaining torque or tractive force can then be applied to overcoming inertia.

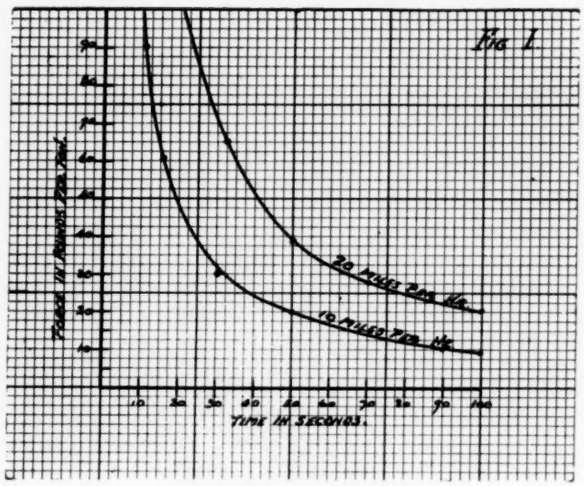

FIG. 1.

Much study has been given to the resistance of freight cars operating at various speeds. In Industrial Plants, we are primarily interested in starting and stopping and operating trains, at low speeds, therefore this phase of the subject should be briefly discussed.

The curves in Fig. 2 show resistance in lbs. per ton plotted against speed in miles per hour. Cars of great capacity will show lower friction per ton and smaller cars more than that shown on the curves. It should be noted that the lowest friction at about 7 miles per hour for the two types of bearings is not far apart, but the breakaway friction of M.C.B. bearings is 3 to 4 times as great as for roller bearings. In Industrial Plants, breakaway friction is a very important factor. With M.C.B. bearings especially, weather conditions influence the breakaway friction as well as the running friction until after the cars have moved enough to cause the heavy oil or grease to soften.

Assume a train of 5 cars of 60 tons each being handled by a locomotive of 25,000 lbs. tractive force.

Breakaway resistance is 300 tons x 18 lb. per ton equals 5400 lbs.

25,000 lbs. less 5400 equals 19,600 lbs. for acceleration.

Wt. of locomotive would be about 50 tons.

Total weight of train 350 tons to be accelerated

$$\text{force per ton } \frac{19{,}600}{350} \text{ equals } 56.$$

Referring to curves on Fig. 1, this will accelerate train to 10 miles per hour in slightly less than 20 seconds on straight level track.

Friction at 10 miles per hour has dropped from 18 lbs. to about 4 lbs. per ton, so that the average is about 11 lbs. per ton, or a total average resistance force of 3300 lbs. instead of breakaway friction of 5400 lbs., neglecting friction of locomotive bearings.

In actual practice there are several factors that may prevent making this theoretically possible time.

1—Track may be poor, which not only increases the rolling friction, but may cause wheels of

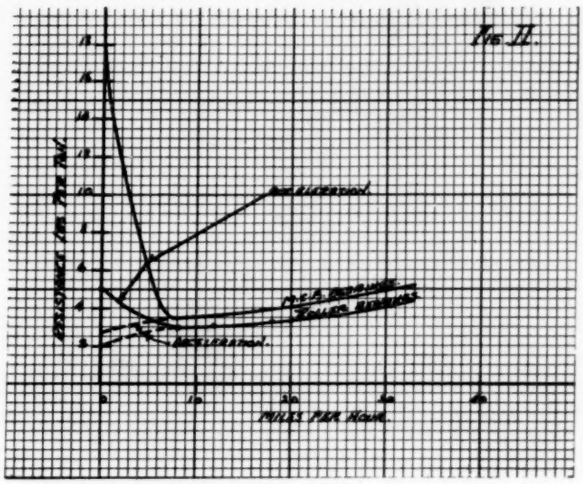

FIG. 2.

locomotive to slip at lower tractive force than 25,000 lbs.

2—Grades and curves both add to the friction.

3—Cold weather would materially increase friction of M.C.B. bearings especially if the cars had been standing for many hours.

LOCOMOTIVES

Many types of locomotives have been proposed and developed, some of which, have proven successful and many others abandoned for various reasons. Some locomotives have failed in one service and proven highly successful in others.

A description of all the various types of locomotives would not only be a tremendous task, but of no particular value in this discussion. Therefore only some of the more recent types and sizes suitable to Industrial Plant shifting will be discussed.

In shifting work one of the most important and frequently forgotten items is load factor. Load factor means the ratio of average load to maximum load and is always less than unity.

Even if measured for a short time, the load factor of a job is seldom near unity which means that there is no need to design a locomotive to do continuous work when it is to be used in Industrial Plant shifting. About as high a load factor as is ever encountered in shifting work is 25% and the average is more nearly 15%. This means that the average load over an 8 hour period is 15% of the maximum load or rated capacity of the locomotive. If the load factor is taken for a longer period of a month or year, it will be even less than 15% because idle periods will be included.

STEAM ENGINES

The modern shifting engine is a good reliable piece of machinery, one that has been well designed for many years, and one that has had many years of careful thought as well as thoughtful operation applied to its various weaknesses, as they became apparent, and for very heavy work it is probably still the best unit available.

The boiler of the steam engine is its weakest point, but much can be done to improve its operation by careful attention to feed water, boiler blow down (preferably continuous) and handling of fires; but these points cannot be covered in detail here.

The tractive force of a steam locomotive in pounds equals .85 x steam pressure in lbs. x (Diam. of cylinder in inches)^2 x stroke in inches, divided by the diameter of driving wheel in inches. Thus a given engine will have double the tractive force with wheels 2 ft. in diameter as 4 ft. in diameter, and four times as much tractive force if the cylinder diameter is doubled. The proper ratio of cylinder and wheel diameter is very important in a shifting engine, where so much of the time is devoted to acceleration. The weight on drivers limits the tractive force and all engines are designed to slip their wheels with full steam pressure applied to full stroke of the piston.

Since, in shifting work, speeds above 15 to 20 miles per hour are seldom required, the steaming capacity of the boiler can be reduced somewhat below that of a locomtive for use on main line work but the boiler must be able to supply sufficient steam for the longest run at the desired speed.

The **objections** to a steam locomotive are:

1—Smoke, dirt and live sparks as a fire hazard as thrown from the exhaust.

2—Loss of time due to stopping for required boiler washouts and boiler repairs.

3—Cost of fuel and repairs to boiler.

4—High cost of standby fuel if work is discontinuous.

5—Coaling, watering and fire cleaning as lost time.

6—Starting tractive force not uniform throughout complete revolution of driving wheel, hence liable to cause slipping of wheels.

The **advantages** of a Steam Locomotive are:

1—Low first cost.

2—Tractive force may be constant within steaming capacity of boiler, thus giving high accelerating capacity.

For very intermittent service, and where live steam is available, fireless steam locomotives have been built which carry a boiler partly filled with water and well insulated to prevent loss of heat into which is pumped superheated steam to some predetermined pressure. In service, the engine draws on this supply of steam, just as in a regular steam locomotive. This saves loss of fuel due to intermittent firing, eliminates boiler repairs, eliminates smoke and dirt and makes a very simple and effective unit for service within its capacity. Such units stand out as very useful in times of extremely low operation where producing departments require very intermittent shifting service.

The compressed air engine operates on about the same basis as the storage steam unit and is a very useful unit where live steam is not available, or where the heat or moisture in the exhaust from a steam unit would prove objectionable.

The characteristic curve of a steam locomotive is shown on Fig. 3. If the Boiler had infinite steaming capacity, the curve would be practically horizontal. The break in the curve depends on the steaming capacity of the boiler and cut off rather than on the cylinder and driving wheel design. With the storage steam or air engine, the curve has about the same shape except that as steam or air is taken

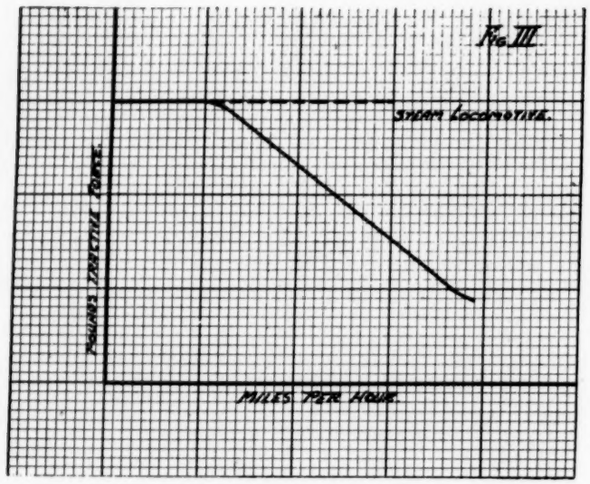

FIG. 3.

from the boiler the pressure drops which reduces the tractive force in direct proportion.

ELECTRIC LOCOMOTIVES

This classification includes all locomotives which derive their power from electric motors without reference to the source of the electric current. The motors may be built on the axle of the driving wheels, geared directly to the axle or connected by means of connecting rods and gears to the axle. In order to fully appreciate the operating characteristics of an electric locomotive the fundamental characteristics of a series wound D.C. motor should be made clear, because, regardless of the character of the motor actually used, its characteristics are made to approximate those of a series wound motor as closely as possible, because they are almost ideal. The only exception to this being, main line electrification where regenerative braking is considered essential, but since we are considering shifting work only, this phase of the subject will not be discussed.

The characteristic curves of a D.C. series motor are shown in Fig. 4.

Torque equals a constant x magnetic flux x current.

Flux is proportional to current within magnetic saturation limits of any given motor, therefore:—

Torque equals a constant x $(\text{current})^2$

$$\text{Speed equals a constant } \frac{\text{volts}}{\text{flux}}$$

$$\text{equals a constant } \frac{\text{volts}}{\text{current}}$$

Torque is proportional to the square of the current. Speed is proportional to the voltage applied to the armature and inversely proportional to the current. If the voltage is halved the speed is halved, but if the current remains constant, the torque remains the same. This characteristic is used in starting locomotives by connecting the motors in series, the current producing a starting torque in each motor of just as great a value as if full voltage was applied to each armature.

The speed of a series motor builds up rapidly or slowly depending on the inertia and load resistance. As it builds up, the current decreases, which in turn decreases the torque inversely as the square of the current until the load, due to acceleration and friction, is equal to the torque of the motor, then no further increase in speed takes place. At this point, if greater speed is desired, the voltage impressed on the armature must be increased in order to cause more current to flow. This is usually accomplished by reconnecting the armatures, so that a lesser number are in series, and so on until the full voltage is across each armature.

Horse-power or kilowatt input to motors is measured as the product of the current and the impressed voltage. When there are a number of armatures in series, the total current is low and the h.p. input small as compared to the input when the armatures are in parallel and each one taking its full current, but the torque remains great because it is independent of the voltage across the armature.

Horse-power as shown above is force x average speed. Torque and force are the same so far as this equation is concerned, therefore we can write:—h.p. equals torque x speed. Therefore the summation of the torque exerted by all the motors, x the speed of the locomotive is equal to the h.p. output of the locomotive which is also equal to volts x amperes input to the motors x motor efficiency, therefore we may write:—volts x amperes, equals torque x speed.

There are two general classifications into which all electric locomotives may be divided.

1—Those which obtain their energy from a source external to the engine.

2—Those which are self-contained.

(a) Those carrying a storage battery.

(b) Those having a prime mover connected to a generator on the engine.

The electric locomotive which depends on a third rail or overhead contact system is not practical in many Industrial Plants, because of the cost of such a contact system with reference to the traffic density and also due to its interference with other activities about the plant. However, where there are movements confined to definite locations such as transfers from one building to another, and where a simple contact system can be set up that does not interfere

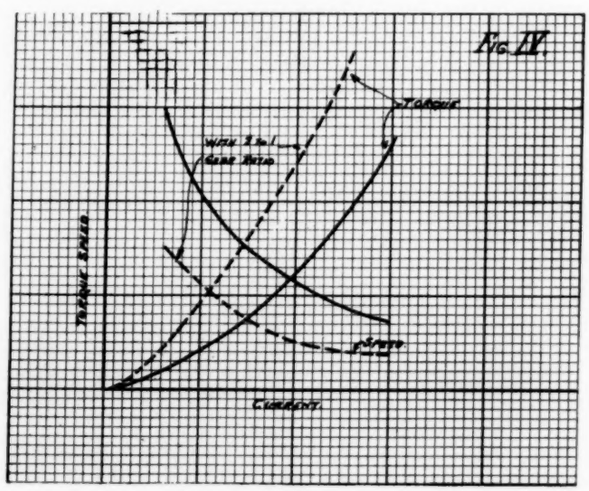

FIG. 4.

with other operations, there is no other form of electric locomotive that will do as good a job, because the energy used is cheap and the amount of power is limited only by the adhesion to the tracks, and size of motors on the axles, and the cost of the locomotive is low. Where distances are short, and voltage and power not too great, a trailing cable with a take-up reel offers a very satisfactory solution, making an installation of low cost and high reliability. This form of contact system has been brought to a high state of efficiency in the mining industry.

The Storage Battery Locomotive has a very definite place in the shifting problems of the Industrial Plant. It will do any of the jobs any other locomotive will do within the range of the energy stored in the battery, and is especially valuable where a few extremely heavy loads are to be moved at infrequent intervals, such as a few hours work, on each turn, with ample time in between for charging or on one shift of average work with time for charging on night turn. Energy for a storage battery is ordinarily available at a very low cost compared to the price of fuel in other locomotives. It is even less than in an electric locomotive taking its energy from a contact system, inasmuch as the battery can be charged at night and off the peak of the electric load of the Plant. When this energy is generated in the plant, only the increment cost of energy on night turn should be considered, which, for a plant of fair size, should not exceed $.004 to $.006 per k.w. hr. When power is purchased, the cost is the lowest step in the contract for energy only, since the demand is usually set on day turn. For plants having a demand of 500 k.w., this should not exceed $.008 per k.w. hr.

The cost of battery renewals depends on the character of load, but per k.w. hour of current taken out of the battery is approximately $.036.

There has also been developed, a combination contact and storage battery locomotive in which the locomotive operates as a contact locomotive when a contact system is available and at the same time charges the battery, if it needs to be charged, and operates on battery when it becomes necessary to go into buildings, or on to isolated tracks, where no contact system is available. This form of locomotive permits complete electrification and avoids the first cost of a contact system for those parts of the trackage little used.

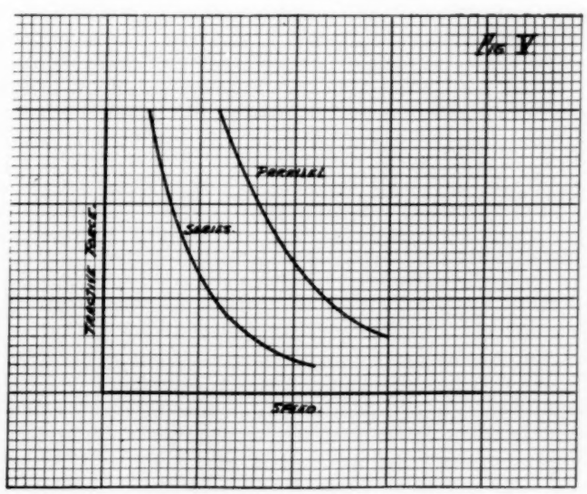

FIG. 5.

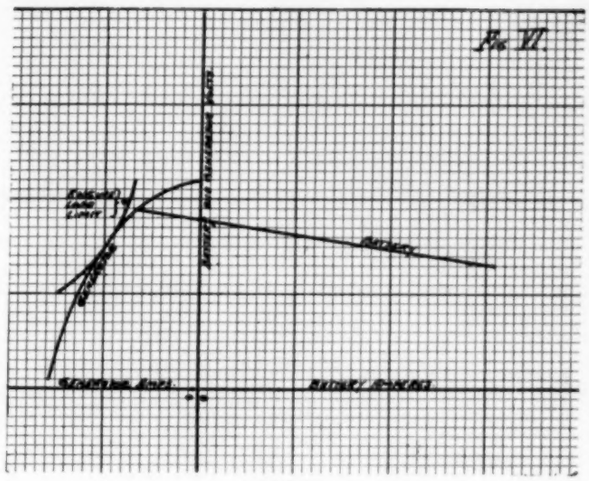

FIG. 6.

The operating characteristics of these various types of electric locomotives are all quite similar, since they are supplied with constant potential.

The characteristic curves of any particular locomotive will depend on the characteristics of the particular motor used and the gear ratio, as well as the number of motors and their connections. The curves on Fig. 5 are typical, but the principal factor of interest is that the torque or tractive effort is proportional to the square of the current or inversely as the square of the speed for any given connection of armatures.

The class of electric locomotives which carry their own prime mover, all go back to the Heilman Steam Locomotive, built in 1893. The prime mover on this locomotive was a cross compound engine, 500 brake h.p., 300 RPM, directly connected to a D.C. generator rated at 1025 amperes, 400 volts. There were 8 motors on the axles.

This type of locomotive did not show very great advantages over the conventional engine with the cylinders connected directly to the driving wheels, so that today we need only consider those which use an internal combustion engine as the prime mover.

The operating characteristics of these locomotives are quite similar to the electric locomotive, having constant potential, except that maximum starting efficiency is obtained by controlling the voltage of the generator thus eliminating the rheostatic losses incurred in starting a constant potential locomotive.

In order not to stall the engine, it is necessary to limit the output of the generator. This is accomplished by various special designs and schemes of control so that the product of volts times amperes does not exceed the capacity of the engine.

This is shown on Fig. 6, the volt ampere curve of the generator always lying just under the limiting curve of the engine. At low speeds this limit of power is no handicap in performing work but usually at about 4 miles per hour, there is a deficiency in power which does not exist in the constant

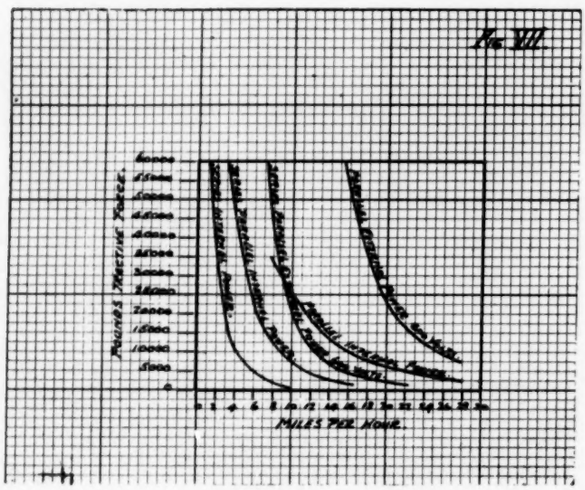

FIG. 7.

potential unit, taking power from a contact system or battery.

This limiting factor in the gas or oil-electric locomotive has been partly met by a combination engine and storage battery unit, in which an engine of somewhat smaller size is used than for the straight engine type, the battery acting as a flywheel and enabling the combined engine and battery to deliver to the driving motors, power for short intervals of time greatly in excess of that which can be delivered by the engine alone on an equivalent locomotive of the straight gas or oil type. The ratio of size between the battery and engine is determined by the load factor of the work to be done. Fig. 6 shows how the battery and engine work together.

The battery characteristic curve is a straight line, that is, the voltage delivered by a battery is inversely proportional to the current being delivered, other conditions remaining equal.

As output of generator is increased, its voltage drops which permits the battery to discharge. As energy is taken from the battery, its voltage drops so that when the output of the generator is low and its voltage builds up, the battery will take current from the generator thus maintaining a balanced condition.

Fig. 7 shows some characteristic curves of electric locomotives using both external and internal power which illustrates the effect on Tractive Force of limits in available energy.

Fig. 8 shows some characteristic curves of steam and oil-electric locomotives. The fact should be noted that the steam engine maintains its maximum tractive force up to about seven miles per hour while the oil-electric begins to drop at about two miles per hour. These curves show that the electric locomotive of about the same weight will start a train from rest that the steam unit cannot move and in the case of the 800 h.p. oil-electric unit, will accelerate up to 4 miles per hour at a higher rate, but above this speed, the steam engine will accelerate faster.

In shifting work, however, the real measure of a locomotive is how quickly it can accelerate a given train up to some given velocity.

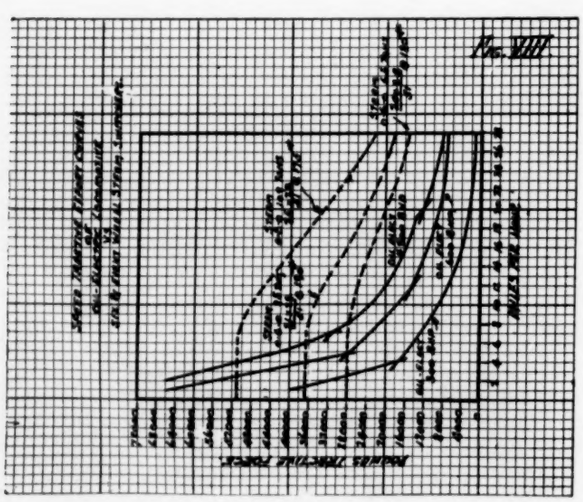

FIG. 8.

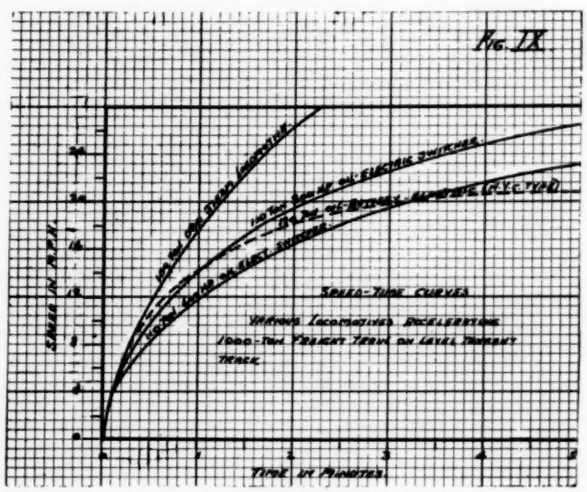

FIG. 9.

Fig. 9 shows the speed time curves of several locomotives of about equal weight accelerating a 1000-ton train.

From the above data it is evident that for a given weight locomotive, the steam unit will do more shifting per day than any of the electric units, if ability to accelerate is the only factor taken into consideration. But, from a practical operating point of view, the unit with smaller tractive force can accelerate light loads as fast as the load will permit from other considerations and in industrial plants the percentage of light loads is very high, so that many factors other than tractive force must be considered in determining the volume of work that can be done in a day by a locomotive in an Industrial Plant.

Comparing the oil and gas-electric with steam locomotives, no time need be taken out for taking on water and coal for the former, also boiler washouts and boiler inspection are eliminated. The fuel for the oil or gas-electric, being small in bulk and liquid, can be taken on in a very short time and

TABLE I

Kind of Locomotive	B.t.u. Per Gallon	Price Per Gallon	Price Per Million B.t.u.	Efficiency of Engines	Cost Per Million B.t.u. Output of Engines	3415 B.t.u. Per k.w. hr. cost per k.w. hr. at the driving wheels allowing 85% efficiency for generator & 85% effi. on motors	Cost per Loco. Hr. Assuming Average of 50 k.w. hrs. Per Loco. Hr.	REMARKS
Steam	Per Net Ton, 27 Million	5.00 per ton	.185	6%	3.09	.009	.45	Includes boiler efficiency but no allowance made for efficiency of connecting rods.
Contact Electric						.008 to .015	.40 .75	Depending on cost of power.
Storage Battery						.0069 to .011	.35 .55	Depending on last step in cost of power, if purchased; and increment cost if made; and taking into consideration, efficiency of battery.
Combination Engine and Battery	144,000	.05	.347	26%	1.33	.0054	.27	Efficiency depends on 40% of energy going direct to motors and 60% going in and out of battery.
Gas-Electric	124,500	.09	.723	20%	3.62	.0147	.74	
Oil-Electric	144,000	.05	.347	30%	1.15	.0047	.24	Heavier oils will cost less per gallon and weigh more. B.t.u. cost will be lower than ratio of prices.

other supplies can be taken on with change of crews. Shop time for these units is much less than for steam locomotives. An availability of 60% is about the average for steam locomotives, where as a gas or oil-electric can easily show 80 to 90%. So, if it requires six steam locomotives to keep an Industrial Plant running, four gas or oil-electric locomotives of equivalent size will do the job, if the work can be properly spread over the day and week.

Locomotives, however, cannot be judged entirely on their ability to do work for just as in every other phase of industrial plant work, cost must be considered.

Table I shows cost of fuel for the various types of locomotives. In the case of the steam engine, credit is given because the device connecting the cylinder of the engine to the drivers is very efficient as compared to an electric transmission system of generator and motors.

Table II shows the maintenance cost per locomotive hour of the various types of locomotives. In this connection it should be noted that maintenance, to some extent, varies with the load factor, being greater for the heavier work, but the running time for the locomotive also has a very decided influence on the total figure. These figures are taken from many sources and are to be considered as lump sum averages for locomotives 50 to 100 tons weight operating at about 15% load factor. The items included are, repairs to all parts of the locomotive, supplies and lubricants, cleaning and repainting, water for the steam and battery locomotive, battery renewals and repairs to contact system for contact electric locomotive.

TABLE II

	Maintenance Per Locomotive Hour
Steam	2.10
Contact Locomotive	.30
Storage Battery	2.00
Combination Engine and Battery	1.00
Gas-Electric	.50
Oil-Electric	.80

For small size units of less than 20 tons capacity, there are available several types of gasoline and Diesel oil engine driven locomotives of the mechanical transmission type which are very efficient within their ratings. They are usually equipped with a four-speed gear shifting transmission and friction

clutch, which facilitate starting under load. For low load factor light work, these units must be given full consideration. However, the unit figures shown in Tables I and II will not apply except in a very general comparative way.

FIRST COST

The first cost of a locomotive varies with its weight as well as with its h.p. and since a locomotive should be able to slip its wheels at standstill, the gear ratio between the engine and drivers determines the h.p. for any given weight locomotive. A high gear ratio will enable a low h.p. rating to start a given load but will limit the speed with which the locomotive can work. If high speed is not needed then it is extravagant to provide great h.p. in a locomotive.

Table III shows average costs for various types of locomotives designed for shifting work.

TABLE III

Type of Locomotive	Cost Per Ton Wt. on Drivers	Hrs. Work Per Year	Cost Per Locomo. Hr. Per ton at 13%
Steam Locomotive	$500.00	6,000	$.011
Contact Electric	600.00	8,000	.0097
Storage Battery	700.00	4,000	.023
Combination Engine and Battery	800.00	7,000	.015
Gas-Electric	950.00	7,000	.0176
Oil-Electric	1,000.00	7,000	.0185

The capital cost per locomotive hour depends on the number of locomotive hours per year that the engine can work. This depends on the work available as well as the ability of the engine to stay on the job. The steam locomotive is at a disadvantage inasmuch as it must be put in the shop for boiler washout and boiler inspection at regular intervals so that the hours work possible per year is somewhat less than for the electric locomotives.

OPERATING LABOR COST

This item depends on local conditions and so far as the total costs are concerned depend on the hours worked and for any type of unit will be relatively the same except that the unit which will get the job done the quickest will have the lowest labor cost. This emphasizes the value of having a locomotive of ample size for the work to be done.

Labor cost for one type of unit as compared with another, carries one advantage in favor of all the electric units over the steam units, namely the elimination of the Fireman.

TOTAL OPERATING COSTS

It should be noted that there are three general divisions to the total cost of doing shifting work.

(1) Fuel and Labor.

These two items depend on use only i.e., they do not cost anything unless the locomotive is in service except a small item for fuel of banked fires in case of steam.

(2) Maintenance.

This item depends largely on use, that is the more continuously and harder a unit is used, the more its maintenance cost will be, but there are a number of items in maintenance that depend on time as well as use, for instance, the wear on flanges of wheels, lubricating oil, wear on bearings, rust, damage to paint, etc., all continue under light work and to some extent when no work is being done.

(3) Capital cost.

This item depends on time only.

In order to choose a unit to do a particular job at the lowest cost a careful study should be made to determine:

(1) The maximum tractive force required.

(2) The average tractive force required.
From 1 and 2 the load factor is determined.

(3) The speed at which it is necessary to move.

(4) The number of hours per day necessary to do the work, and whether work can be arranged so it can be done in shortest time possible or whether other operating conditions make it necessary to spread work over a greater length of time.

(5) Conditions of smoke and noise permissible.

(6) Fire hazards.

(7) Conditions affecting installation of electric contact system.

1. If the work is continuous and the ratio of average to maximum tractive force high, then a unit of high efficiency, low fuel and labor cost is indicated such as the contact or oil-electric locomotive.

2. If the work is intermittent with a low ratio of maximum to average tractive force, then a unit with high overload capacity, with possibly a low efficiency at the maximum load but with good efficiency at fractional loads and with low standby expense, is indicated such as the combination battery and oil or gas engine.

3. If the work is confined to one shift only, with a prolonged idle period, a unit of low first cost and low standby cost is indicated, such as the storage battery.

4. If the work can be concentrated within one or two days per week, then a unit of low first cost is of prime importance and a steam engine is indicated, unless fire hazards or smoke ordinances prohibit.

5. If the work is of intermittent nature, but periodic during the day, the storage steam or air locomotive is indicated.

In conclusion, it should be emphasized that for Industrial Plant shifting, there is a best type of unit for the various working conditions to be encountered and only a careful analysis will show which unit this is. There is no universal panacea for all the kinds of shifting work to be found in Industrial Plants.

Discussion

Discussion Presented by

W. H. Burr, Electrical and Mechanical Supt., Lukens Steel Company, Coatesville, Pa.
W. L. Garrison, Asst. Mgr., Locomotive Dept., Ingersoll-Rand Company, New York, N. Y.
R. K. Mangan, Sales Mgr., Industrial Division, The Buda Company, Harvey, Ill.
J. H. Tracy, Engineer, Electric Storage Battery Co., Philadelphia, Pa.
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O. J. Gilcreest, Engineer, Transportation Dept., General Electric Company, Schenectady, N. Y.
G. J. Walz, Asst. Elec. Engr., Bethlehem Steel Company, Steelton, Pa.
D. M. Petty, Superintendent Service Division, Bethlehem Steel Company, Bethlehem, Pa.

W. H. Burr: It has been some little time since we have had Dave Petty on our program in the Philadelphia Section. It is indeed a privilege to have him here and he has taken care of this paper this evening in the same thorough and efficient manner which he always does and delivered it in the characteristic style of Dave Petty. His paper has a lot of food for thought in it, more than we can grasp in the short time which we have to consider it tonight.

Our switching at Lukens is all narrow gauge; in fact, only 30 inches. Like Topsy the system just grew. All standard gauge switching is done by the Reading Railroad. Our plant is located on both sides of the Reading Railroad and to provide a safe crossing a tunnel was placed under their right of way. This limits the height and width of the locomotives and the curves in the old section of the plant are of such a radius that the length is limited to a certain extent.

To make matters even worse our slag dump is located on a hill west of the plant which made it necessary in the early days to have hill climbing locomotives. To supply the demands on the 206" Plate Mill, ingots weighing 90,000 pounds are handled between the Open Hearth and mills with these narrow gauge locomotives.

For years we operated only steam locomotives and quite a fleet of them too. The shifting locomotives were twenty-five ton capacity and the hill climbers were of the gear driven type and thirty ton capacity. Some two years ago we installed a gasoline locomotive twenty-five ton capacity of welded construction. Its operation was so satisfactory that a second one has been installed.

For the purpose of comparison let us assume that the locomotive hours per period for Gas and Steam driven locomotives is the same. On this basis the cost of fuel for the Gasoline locomotive exceeds that for Steam locomotive.

The cost of Labor in Repairs and Maintenance on the steam driven equipment is greatly in excess of that on the gasoline engine. Material in Repairs and Maintenance is in favor of the gasoline although the saving is not as great as on Labor. The oil required by the gas locomotive exceeds that on the steam driven engine.

Then on a basis of cost of operation including Fuel, Oil, Repairs and Maintenance the cost of operating the gasoline locomotive is only two-thirds of the cost of operating the steam locomotive.

It is true, of course, that the steam locomotives are much older than the gasoline locomotives which will have some bearing on the maintenance cost.

I was somewhat skeptical of the operation of these new engines and expected some trouble during cold weather, but must admit that so far they have made a very favorable showing.

W. L. Garrison: Gentlemen, Dave Petty is the instigator of my being here. I want to say that I have gone over his paper. I have worked with him for several years and know that he has tried almost every type of locomotive now in existence. I appreciate very much that he has some real foundation for his statements.

I am not going to talk steam because I am not a steam man, I am going to leave that to the steam men; I am going to ask you to discount my statements if you will, because I am going to stick to oil-electrics as I have been with them since they started in 1924. Steel mill switching, as has just been stated, has grown by evolution and the steel mill was originally built without much consideration of the transportation problem and that's the reason why you have so many tight corners and so many serious grades to contend with. It has been predicated on steam so that your transportation cost figures have been based on steam alone.

Recently, there have been several new types of locomotives developed to compete with steam and I will say that today all the steel mills of reasonable size are seriously considering the new forms of power and they are analyzing them the way Mr. Petty has been analyzing his.

Now, there must be some reason for this development, and I am going to talk oil for the reason, that there is economy in oil. There is no motive power unit with a higher thermal efficiency; the thermal efficiency of the oil engine is from thirty to thirty-three per cent. When you place such a power plant in a locomotive the thermal efficiency of the complete machine, from the power input to the power out of the wheels, is about 25 per cent, and if you will consider the steam switcher today, not a new machine but the one you contend with every day in your service, you will find by actual test that instead of having six per cent thermal efficiency as Mr. Petty has stated, you will have nearer one and a half to three per cent.

I happen to have with me a test conducted by one of the big railroads in Canada on a six-wheel switcher in good condition of about 1200 cylinder horsepower. The average cylinder horsepower developed in actual switching service was only 66.7 horsepower, and the maximum for one minute duration was 470 and the maximum for fifteen minutes duration was 360. That explains immediately why an oil-electric locomotive, with much less oil-engine horsepower, is able to do the switching work of a steam locomotive with considerably more cylinder horsepower.

There may be some jobs where a large steam

switcher is necessary to handle a small percentage of the work during the day. Oil or gas electric locomotives offer the advantage of multiple unit control. That is two or more units may be operated as articulated units under one crew to cover the heavy jobs of short duration and then broken up as separate units for the lighter jobs. This is actually being done in a Kentucky steel mill today. In some steel mills multiple unit operation offers the advantage of standardization in sizes of locomotives.

I wish to point out that the growth of the oil-electric locomotive has been exceedingly rapid since 1924, this you will realize if you stop to think that the world today—Siam, Russia, Germany, Denmark, Sweden, England, Argentina, Costa Rica, Colombia, Manchuria, Algiers and Tunis—all are using oil-electric locomotives; there are seven operating out of Bangkok, Siam, alone today and more being built. Even in the U. S. A., in this depression, there have been nine oil-electric locomotives sold this year since January 1.

Now, the reason for this development, is again, due to the electrical engineers, so I feel that I am among friends in talking straight from the shoulder. The control that has been developed has made possible not only the oil-electric locomotive and rail car, the gas-electric and oil-electric bus, but also the A.C.-D.C. locomotives on the New Haven which use the same principle of control as that we are using on the oil-electric locomotive.

There are a few points that I want to bring out in connection with Mr. Petty's paper; one was raised on the floor that was a mighty good point and that is about a locomotive getting off the track. With a steam locomotive, particularly with a three-axle six-wheel switcher, it is quite a job to get it back on the track and we have a job in New York City, to show you how important it may be, where there are ninety foot radius curves around a warehouse. They depend upon only one locomotive and if that goes out of service they have to go to Jersey City and float another one over to New York. The freight made up there must make connections with Jersey City to go out on the westbound through freight, and is important. When the steam locomotive went off the track it sometimes took a day to get it back on with a repair crew from Jersey City. The oil-electric, with flexible trucks, can be blocked up, one axle only, to get a pair of wheels on the tracks and then you can pull all the rest of it back on. We are allowed one hour to get back on the track; so that can be capitalized into actual savings, in a great many cases.

I agree thoroughly with Mr. Petty that there is no one locomotive that will handle all switching jobs and that you have to be very careful in the selection of your power, particularly today, to get the most economical results and to avoid a mis-application.

The oil engine no matter whether it is a small one or a large one, has the same thirty to thirty-three per cent thermal efficiency so that the fuel consumption per brake horsepower hour averages very closely, on any size, to .4 pounds per brake horsepower hour, and you can maintain this efficiency on the oil-electric, whereas you will lose it more rapidly in the steam locomotive because it depends upon open combustion and boiler and cylinder losses, which you haven't got in an internal combustion engine drive.

There was a point raised that the horsepower of the oil-electric is limited. This is not so; we can go to four thousand horsepower on an oil-electric if there is a job to warrant it. The size depends entirely upon the work to be done in the plant and should be based on the hours required for that work so that it may mean a three hundred or a six hundred, or maybe, a 1600 horsepower locomotive.

In this development, one of the serious disadvantages of the oil-engine and the electric transmission is the first cost, but it is also true that the development today and the depression are hastening the time when this will be overcome.

I have heard several arguments only recently that it is not fair to compare a new oil-electric or a new gas-electric with an old steamer, and I dispute this for the reason that we don't propose to set up the maintenance of any one year. It is true that any locomotive, when it is new, can be maintained for less than when it is twenty-five years old but the maintenance figures that determine the economic locomotive to use is the average maintenance over its life. In other words, we are not comparing the maintenance of the oil electric in its first year with the maintenance of the steam locomotive in its twenty-fifth year.

The question of obsolescence has been brought up. That is a very good point but, unfortunately, in the last three or four years it hasn't carried much weight because there are—hundreds of locomotives in service today, long since obsolete but it is now a question of capital and service requirement as to whether they can be replaced or not. I don't think obsolescence has been given the weight that it should have, due to the financial conditions throughout the country. What is more important is that the locomotive, in its twenty-five or thirty years of life, should do their work year in and year out and do it economically and effectively.

R. K. Mangan: Mr. Petty's talk has indeed been very educational to me, as well as the general discussion here this evening.

Our company has manufactured gasoline engines for locomotive service for approximately fifteen years, and the Buda-M.A. N. Diesel engines for about six years. We feel sure in the larger size locomotives, especially from 20 tons up, the gasoline engine is being obsoleted quite rapidly by the Diesel engine.

In the discussion here this evening it was brought out that the cost is keeping the Diesel engine from advancement. We of course all know that if production on a certain item is started and a volume is reached, the price will come down. We feel we are about on the verge of a considerable increase in Diesel engine business, which will mean our production will be increased to such an extent that we can afford to bring our prices down.

Several of the locomotive manufacturers prefer to use electric drive above 20-tons instead of straight friction. This is due to clutch trouble.

J. H. Tracy: I want to add my word of congratulations to Mr. Petty on the thoroughness with which he has gone into this problem. Now it may be a little presumptuous for a man in the storage battery business to talk about locomotives; I do not pose as a locomotive expert.

There is one point however, which has come to my attention and that is in this figure here—Storage Battery Electric—.35 to .55; for fuel per locomotive hour, Mr. Petty has used a basis of fifty kilowatt hours per hour. That figure I believe to be high, except on the basis of probably a hundred ton locomotive. In switching work I have been led to believe that the maximum that has ever been recorded has been one kilowatt hour per hour per ton of a locomotive, and that figure was only obtained with a third rail or, at least, a contact system locomotive and was considered exceptional. From records which I have seen fifty or, possibly, sixty kilowatt hours per hour for a 100-ton locomotive seems to be about as much as would ever be encountered.

Nothing has been said about the mileage which a switching locomotive actually makes in operation. It is a busy switching locomotive that moves much over two miles in an hour in actual switching service; three miles an hour is accomplished at times, but I believe it is ordinarily the maximum. I think it is a practice of the railroads, authorized by the Interstate Commerce Commission, to figure the miles of a switching locomotive at six miles per hour. That may perhaps be justified on cost accounting for the railroads but I don't think such a figure is likely to be at all approached in any industrial yard switching operation.

R. J. O'Brien: Mr. Petty's paper is a very fine contribution to give the overall picture, economies, costs and fundamentals applying to industrial locomotives. It is very thoroughly presented.

Our experience, as the result of the analyses of many projects, makes us believe as Mr. Petty does, that to determine the type of locomotive, a thorough analysis of costs should be made. We have found, however, it is very difficult to get comparable costs. Take two railroads or industries, and try to compare costs, and you find so many factors enter in that you really can't get more than a rough comparison of some items. I think, in general, Mr. Petty's costs agree with the general range of costs that we use.

I would, however, like to comment on the maintenance costs. Not only does the character of service vary between properties, but one industry or road will have a system of accounting that includes certain overhead, supervisory or other items excluded by another road; maintenance methods, and the number of equipments available to maintain as compared to the size of the maintenance force may be appreciably different. Then, too, the efficiency of the maintenance forces is very variable, so it is hard to get a true comparison.

A consideration of fundamental designs as well as available operating costs is of value in determining relative maintenance costs, especially of internal combustion equipments. This is especially true when comparing gas-electric and oil-electric equipments.

The oil engine for transportation service was developed later than the gas engine, and it has been only in the last few years that it has grown out of the development stage. This should be borne in mind when reviewing maintenance costs of older equipments.

To get practically a comparison in maintenance costs and reliability of two such modern equipments, two United States railroads each bought an oil-electric car and a gas-electric car of approximately the same horsepower size, and in the fall of 1930 put them in service. In each case the oil-electric car and the gas-electric car were in identical service, running opposite to each other, i.e. on the same trains on alternate days. This gives a much better comparison of conditions than is possible with switching locomotive operation because of the variation of the duty cycle for any switching locomotive from day to day. One road continued the opposite running during the more than two and a quarter years, and on the other road the gas car was moved to any run some time last year.

Both the repair—maintenance cost and availabilities, for the last reports available as of some time last year, are favorable to the oil-electric car on both properties.

These records support the belief that fundamentally the only difference in operating cost of oil-electric locomotives and gas-electric locomotives is in the fuel cost.

O. J. Gilcreest: I congratulate Mr. Petty on the very thorough and analytical treatment of this subject. His paper is not only interesting and constructive from an application point of view, but I believe it would serve well as a text-book to students on this subject.

Our Company has no particular brief for any particular locomotive as such; we believe in attacking a problem basically, as Mr. Petty has treated his subject, analyzing facts of each case and making our recommendations stand on those facts.

In Table No. 2 there are some very interesting figures on Maintenance per Locomotive Hour. I understand those figures cover locomotives from 50 tons to 100 tons weight and were intended to be more relative than otherwise. Nevertheless, in connection with the combination engine and battery locomotive, I am inclined to believe the figure of $1.00 is high and out of line with the group. On account of this type of locomotive carrying a smaller engine (prime mover) for a given weight of locomotive than other locomotives of the same weight, and such engines being more of a production unit than the larger horse power engine, it is reasonable to assume the maintenance would be less. For such engines approximately $0.25 per locomotive hour ought to be about right; battery replacement cost would be about $0.32 to $0.35, say $0.33; and the remainder of the locomotive about $0.20, making a total of $0.78. These figures are leased on 85 per cent availability or 7446 hours operation per year.

I want to emphasize these points on the combination engine battery, the gas-electric and the oil-electric type of locomotive—they are a real money maker due to their lower maintenance, higher availability, longer life, and in spite of the higher first cost as compared with steam locomotives.

The economics of these internal combustion locomotives, with or without battery, are that they will pay their first cost out of saving in a surprisingly short time when replacing steam. This indicates a handsome return on the investment.

G. J. Walz: I feel that our old friend, Mr. Petty, has covered his subject, as he usually does, in such a masterly and capable manner, that he has made it extremely difficult, for anyone to add anything of real value to his interesting paper.

However, we have been rather fortunate at the

Steelton Plant of the Bethlehem Steel Company, in having obtained about six and a half months ago, a modern 70-ton Gasoline-Electric locomotive, for plant shifting service. Since the first cost of such a locomotive is really high, and ours was bought when money was very scarce and when we had a whole herd of steam locomotives standing idle in our yards, our Management and Engineers must have seen a great deal of merit in such a proposition.

Our plant is running at such a very low rate of operation, and has been, since we received this new locomotive, that this one machine working only 50% of full time is easily able to do all the shifting for the entire works. In doing so, it is working on a schedule, which is made to order for a gas-electric locomotive;—it works two six-hour turns on each of the first five days of the week, and one six-hour turn on Saturdays and one six-hour turn on Sundays. Our plant is far from being concentrated, its over-all length being about three and one-half miles, so that, in doing the shifting, there is probably more mileage to cover than there would be in many other steel plants.

Our Transportation Department has figures, which show that the gas-electric locomotive does about 20% more shifting work, that is, handles 20% more cars per engine service hour, than a steam locomotive actually has done and would do, under the same conditions. It is somewhat slower on the grades, but faster and snappier on the level, and since the plant only has a few grades, the net result is that it is able to do more work than a steam locomotive.

The labor saving effected by it is more than one would expect at first glance. For instance, we were able to shut down entirely our coaling station, which had required one attendant at all times. When a steam locomotive was used in such an intermittent manner, we had to have a hostler at our shifter house, and the locomotive fireman has, of course, also been eliminated.

The most striking feature about the performance of the gas-electric locomotive, has been its remarkable freedom from operating troubles or delays. During those six and a half months, it was out of service less than 30 hours, on account of breakdowns, and our Transportation Department is of the opinion that a large part of this time lost could have been avoided, had our operators been somewhat more experienced in handling the locomotive. For instance, here is one typical delay: The sand is forced out of the sanders down to the tracks by compressed air, and during the first month or so, an inexperienced engineer forced all the sand out, which, in turn allowed so much air to escape, that the pressure dropped so low that the air operated electrical contactors would no longer function properly; so that when he tried to close the main reversing contactors, they burned fast, and put the locomotive out of commission. With this experience in mind, the operators will probably never again have any delays from this cause. It is really remarkable to find that a piece of machinery as complicated as this is, and having so much electrical equipment on it, can be operated for six and a half months, with practically no time lost on account of break-downs, even though we discount the fact that the locomotive is still new. In fact, our Transportation Department advises that their steam locomotives, which have always been considered the last word in reliability, were never as free from operating troubles as this new machine. Any comparison between the two, to be fair, must, of course, take into consideration the fact that the first cost of the gas-electric is just about 50% more than that of a similar steam locomotive.

I would like to add that the repair and maintenance cost figures which Mr. Petty has given in his paper, check very closely with the actual cost figures which we have obtained during the six and a half months of operation of our gas-electric locomotive, especially the fuel and miscellaneous costs, though our repair expense was almost negligible. Our operating cost figures were a little higher than Mr. Petty's but this is, no doubt, due to our spasmodic and intermittent operation of five twelve-hour and two six-hour periods per week.

D. M. Petty: In summarizing the discussion on this subject, it seems advisable to emphasize a few points.

The advantages of roller bearings over M. C. B. bearings in not only having lower operating friction, particularly at starting, but also the roller bearings have a somewhat lower maintenance cost, so that for cars which are to be operated around industrial plants, it is certainly good business to consider roller bearings on any new equipment and possibly it will be worth while in a great many cases to change over existing equipment from M. C. B. to roller bearings. While this observation is chiefly true on all types of equipment, it is especially true in the case of very heavy equipment, where the load per wheel is unusually high.

I would again emphasize the importance of determining the load factor of the work to be done before any particular locomotive is purchased for a given job, for it is certainly extravagance to purchase, at considerable extra expense, a locomotive which is capable of doing high load factor work when only low load factor work is to be done.

In speaking of the advantages which the electric locomotives have as compared to steam locomotives, it should be emphasized that for industrial plant work, the electric locomotive with the conventional two-axle trucks, with a short wheel base between the axles and connected to the chassis through a king pin, is capable of successfully negotiating curves of much shorter radius than those which a six-wheel shifting engine can negotiate. This is a particularly great advantage in the case of locomotives of 70 tons or greater capacity. Also a truck type electric locomotive is much easier to rerail after a derailment, especially where only one truck has left the rails.

For the reasons mentioned above, an electric locomotive will be able to do more work, owing to the fact that it can operate around curves and through switches at a much higher speed than the 6 or 8 wheel steam locomotive.

One of the hardest factors to control in the operation of a steam locomotive is the fireman. Some men seem to be able to accomplish the day's work by burning much less coal than another man and at the same time always maintain steam pressure without continuously blowing off the safety valve. This element, of course, has been entirely eliminated in the case of the electric locomotive.

There is considerable difference of opinion as to the relative maintenance cost per locomotive hour

of the gas-electric and the oil-electric units. While table two, indicated the gas-electric repairs to be $.50 per locomotive hour as compared to $.80 for the oil-electric, it now appears that these two figures will be very close together and it is very doubtful, in my mind, whether comparative locomotives, doing the same work, will not show substantially the same total cost for maintenance over a long period of time. There are many factors which must be considered in this connection, but it would appear that the simplicity of the Diesel oil engine tends to equalize its heavier parts as compared to the gas-electric with its multiplicity of parts and its rather elaborate timing and ignition system.

It should again be emphasized that in order to determine the locomotive for any particular job, all factors which enter into the job should be carefully considered and the lowest possible cost for doing any particular job does not necessarily mean the lowest cost per locomotive hour, because the time required to do a job is of major importance in determining the cost per locomotive hour, that is, the greater the time, the lower the cost per locomotive hour, whereas actually a lower total cost may result by having a locomotive which is capable of doing the work in a short time.

Design Characteristics That Affect Operation of D. C. Machines

By MAX HARTENHEIM
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The steadily progressing electrification of steel mills and mines requires direct current generators of an output and at a speed which are at the limit of what can possibly be generated in one unit without sacrificing reliability and continuity of service. On the other hand, reversing motors and hoist motors again, although working at lower speeds, often exceed the output possible in one unit from the point of view of shipping the individual parts and assembling as much of the unit as possible in the factory. The latter class of machinery offers seldom any difficulty in the electrical design due to their usually lower speed but what will be said later for the first kind of d.c. generators might be applied profitably also to them.

The large amounts of d.c. energy required in steel mills for instance are converted from the available a.c. supply by means of motor-generator sets, sometimes by rotary-converters. In order to save in space and capital for investment these machines run at as high a speed as is mechanically safe but the limit is given mostly by electrical characteristics, as voltage between commutator bars, commutation, brush distance and others. This requires often the subdivision into several units, and if these have to supply i.e. one single motor an absolutely even sharing of the load by all units can be obtained only by compounding arrangements which are costly, cumbersome and require space and additional apparatus. Every means, therefore, to increase the output in one armature is welcome.

To the designing electrical engineer the building of absolutely satisfactory electrical d.c. machines offers a very fascinating problem and many devices and schemes have been developed to solve it. The problem is, in short, to get good commutation, that is to design an armature winding which will assure this aim. The armature winding almost exclusively used nowadays in this country is the lap-winding with cross—(equalizing) connections. This winding has its limitations as it can never have more parallel armature circuits than there are poles; of course, the number of circuits can be doubled by making two independent windings but this has a rather doubtful value; the interleaving commutator segments do not divide the voltage equally (except by using special means) and mostly two adjacent bars have practically the same voltage so that the voltage difference to the next pair of bars is the same as if only one winding with half the number of segments existed, that is double voltage. A modern generator can hardly be built satisfactorily in this manner.

By far superior is the series-parallel winding or, as it is called in Europe, Arnold-winding, after Prof. Arnold of the Technical University of Karlsruhe, who developed it. It is to be regretted that comparatively little use is made of this not only really excellent, but at the same time extremely flexible winding. The reason is perhaps that it requires careful study and is also mechanically not quite as simple for the shop as the loop-winding. But after some experience with it a designer will hardly use any other winding for difficult conditions and even substitute it for the usual loop-winding with the same number of armature circuits as number of poles.

A few years ago, a kind of combined winding was devised called frog-leg winding, and used by the manufacturers in quite a few cases. But this winding is open to some objection both from the electrical and mechanical standpoint; this was fairly well brought out in the discussion on this winding at the Convention of the A. I. & S. E. E. in 1925. To recapitulate in short, this winding wants to eliminate the cross-connections by using them as active part of the armature winding itself and thus to increase the number of parallel circuits in the armature; they are, therefore, arranged in the same slots along with the usual lap-winding and, consequently, subject to

the same magnetizing forces of the field. The idea is a very good one in itself but it is at once obvious that an equalizing (cross-) connection which is subject to magnetizing, i.e. electro-motive forces is no longer an equalizing connection which can balance the currents caused in the armature winding by inequalities in the magnetic fields. The bad experiences which have often been made with this combination winding corroborate this view and the trouble could have been easily overcome by adding again cross-connections to the windings—which means, of course, adding just the thing which was meant to become superfluous by this kind of winding. To the series-parallel part of the winding the same considerations will apply as set forth in the following.

The aim of this paper is to show how a series-parallel winding is to be designed in order to give the desired result of good commutation under heavy overloads and greatly, suddenly varying loads. To secure this result the winding must be absolutely symmetrical and only singly-reentrant windings must be used. A further requirement is that the current in each armature wire is of a value not to involve too large a current to be commutated and, incidentally, to avoid appreciable eddy currents by having to use too heavy conductors. The series-parallel winding is particularly apt to fulfill these demands as the number of armature circuits does not depend on the number of poles.

For these reasons, it will be almost always necessary that the number of parallel armature circuits be greater than the number of poles which latter is, due to the modern high-speed generator, comparatively low, seldom more than twelve, rather ten or even eight. In order to obtain an absolutely symmetrical, singly-reentrant winding with more parallel circuits than poles the following electrical conditions must be fulfilled:

It be 2p=number of poles,
2a=number of parallel armature circuits,
y=commutator pitch, i.e. from segment 1 to 1+y,
k=number of commutator bars,
Z=number of slots.

These quantities are connected by the equation

$$k = p \times y \pm a.$$

Further, it must be $a = m \times p$, where m is a whole number, mostly 1, 2 or 3,
y and a must have no common divisor in order to get a singly-reentrant winding,
$Z = n \times p$, where n again is a whole number.

In addition to these electrical conditions, very often another, mechanical condition has to be taken care of. Since the iron core of large armatures is mostly built up of segments the number of slots should be such as to be a multiple of the number of segments; this simplifies the manufacture, but it is obvious that it requires often some juggling with figures to satisfy all these conditions.

In order to demonstrate the laying-out of such winding the calculation will now be given in greater detail. It may be required to build a generator of 3000 KW—500 R.p.m.—750 volts—4000 amps. The machine has 12 poles, the armature diameter is 72 in., and the iron core be assembled of 6 segments; the commutator diameter is 48 in. This corresponds entirely to practical conditions regarding circumferential speeds. It will be seen at a glance that for an ordinary lap-winding or, for that matter, also for a series-parallel winding with the same number of circuits as poles (12), that is m=1, the current in each conductor=4000/12=333 amp. becomes too great and the current volume to be commutated too large to insure good commutation. If only one commutator bar (=2 conductors) per slot is chosen the slot pitch is rather small and the machine becomes larger and more expensive on account of the poor space factor. We will, therefore, consider two alternatives, namely m= 2 and m=3, that is 24 and 36 parallel armature circuits respectively, or twice and three-times as many armature circuits as number of poles. The winding data are then:

Number of poles	2p=12	2p=12
Number of armature circuits	2a=24	2a=36
Current in armature conductor, amp.	167	111
Commutator pitch	y=83	y=127
Number of commutator bars	k=510	k=780
Amp.-turns per 1 in. diameter	1182	1202
Volts between commutator bars	17.6	11.55
Widths of commutator bars, inch	0.296	0.193
Number of slots	102	156
Number of conductors per slot	10	10

Comparing these two possibilities it will be seen at once that twice as many circuits as poles does not give very satisfactory conditions firstly because the voltage between commutator bars is rather high, 17.6 volts, for a generator under severe conditions; further, the number of slots per pole is rather small, 102/12=8½. To reduce the number of conductors from 10 to 6 per slot is inadmissible because the winding would not be symmetrical as we would have then 170 slots which is not divisible by the number of pole pairs, 6, and, besides, would not be divisible by the number of armature segments, also, 6, either.

We turn, therefore, to the winding with three times as many circuits as poles and we get satisfactory conditions in every way. The current of 111 amp. in each conductor gives the latter good dimensions, the current volume for 10 conductors per slot =1110 amp. is also a reasonable value; the number of slots is 156 which is divisible both by the number of pole pairs and the number of armature segments. Further, y and k have no common divisor (127 and 780), the winding is therefore singly-reentrant and symmetrical. The voltage between bars is only 11.55, a very satisfactory value which insures a good overload capacity, and there are 156/12=13 slots per pole which likewise is satisfactory. For all these reasons we decide on this winding and will now proceed to find the connecting points for the cross-connections. As we have 780/6=130 bars for each pole pair we come to an equipotential point after having made 130 steps around the armature; the winding pitch is 127 and the winding diagram the following:

1	128	255	382	509	**636**
763	110	237	364	**491**	618
745	92	219	**346**	473	600
727	74	**201**	328	455	582

709	**56**	183	310	437	564
691	38	165	292	419	**546**
673	20	147	274	**401**	528
655	2	129	**256**	383	510
637	764	**111**	238	365	492
619	**746**	93	220	347	474
601	728	75	202	329	**456**
583	710	57	184	**311**	438
565	692	39	**166**	293	420
547	674	**21**	148	275	402
529	**656**	3	130	257	384
511	638	765	112	239	**366**
493	620	747	94	**221**	348
475	602	729	**76**	203	330
457	584	**711**	58	185	312
439	**566**	693	40	167	294
421	548	675	22	149	**276**
403	530	657	4	**131**	258

With bar 131 we have arrived at the first of the six equipotential points corresponding to bar 1 and need go no further. The six columns represent the six pole pairs and show how the winding is distributed. The winding is retrogressive, and having gone around the armature once we arrive at a segment distant from the preceding one of the same circuit by 18=a, the number of armature circuits.

We will connect every fifth bar to a cross-connection which means we have 130/5=26 cross-connections making 20% of all commutator bars cross-connected; this is sufficient for entirely symmetrical winding although there is nothing in the way to increase this number. The underline segments in the winding diagram are those joined to cross-conections, and the complete diagram for the latter is given in the following table:

Equalizing ring	1	to bars	1	131	261	391	521	651
	2		6	136	266	396	526	656
	3		11	141	271	401	531	661
	4		16	146	276	406	536	666
	5		21	151	281	411	541	671
	6		26	156	286	416	546	676
	7		31	161	291	421	551	681
	8		36	166	296	426	556	686
	9		41	171	301	431	561	691
	10		46	176	306	436	566	696
	11		51	181	311	441	571	701
	12		56	186	316	446	576	706
	13		61	191	321	451	581	711
	14		66	196	326	456	586	716
	15		71	201	331	461	591	721
	16		76	206	336	466	596	726
	17		81	211	341	471	601	731
	18		86	216	346	476	606	736
	19		91	221	351	481	611	741
	20		96	226	356	486	616	746
	21		101	231	361	491	621	751
	22		106	236	366	496	626	756
	23		111	241	371	501	631	761
	24		116	246	376	506	636	766
	25		121	251	381	511	641	771
	26		126	256	386	516	646	776

Of course, instead of connecting the commutator bars to the cross-connecting rings the respective armature conductors can be connected as is more usual. In our case, always the first conductor in every slot would be connected to an equalizing ring.

It remains still to determine the diagram for the armature coils. We will number all upper layers of conductors in the slots by the uneven, all lower conductors by the even numbers as shown in fig. 1.

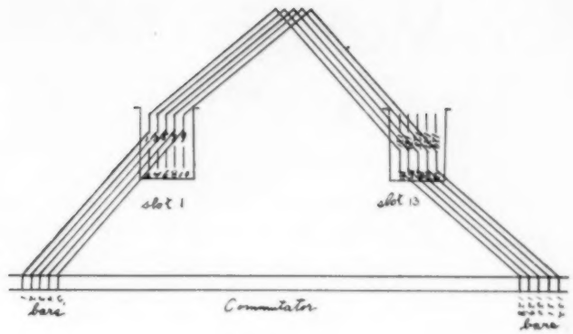

FIG. 1.

Naturally, the pitch of the commutator of 127 applies also to the winding so that conductor 1 in slot 1 should be connected to conductor 128 which is the last but one in slot 13. In order to be able to make complete coils of 5 conductors side by side we connect however not to 128 but to 122, and correspondingly coils 3, 5, 7, 9 to 124, 126, 128 and 130 respectively as shown in the diagram. This gives us a shortened pitch in the winding which is further conducive to good commutation. We must however see to it that the width of the commutation poles is wide enough to still have both sides of the armature coil under the influence of the commutating field. This is a familiar matter and need not be discussed here.

Thus we have finished the design of the armature. But not only for machines for particularly severe conditions will it be advisable to devise a good armature winding, in many other cases will it be found profitable to lay out the winding as outlined before. By going into the details of designing absolutely symmetrical windings with more armature circuits than numbers of poles the author hopes to have shown how the great flexibility of the series-parallel winding makes it always possible to find good electrical conditions for a given case. It requires only a proper study of the winding diagrams as illustrated above which can even sometimes be shortened as the designer becomes more familiar with this winding and overlooks the possibilities with a glance. Electrical and mechanical symmetry thus secured good commutation will result; and it will further be found that the material can be utilized much better. As said before, such generators will always have a compensating winding, but even without this, with commutating poles only, for instance for low speed machines, the commutation will be excellent. This winding leaves a fairly wide latitude in brush quality and width of brushes. Naturally, width of neutral zone, width of commutating pole, and width of brushes, all taken together determine good commutation, but with principal attention given the armature winding it will always be found that a machine works absolutely satisfactorily and is less sensitive even under most rigorous conditions.

Non-Metallic Bearings *

By L. F. COFFIN
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Presented before the Philadelphia District Section of the A. I. & S. E. E., April, 1933.

The conventional bronze bearings, babbitt bearings and bronze-babbitt bearings for rolling mills, with their lubricant packed against the roll neck in the form of a heavy grease, have prevailed in steel mills for so many years as to have seemed to be a vital part of the very industry itself. The waste of lubricant, the failure of this grease to properly lubricate the neck, the high friction loss, the short life of bearings, and the difficulty of holding gauge in finishing stands, has during the past five years forced the bearing problem to the fore, and brought assaults on it from at least three different angles.

We are all familiar with the application of large roller bearings to main rolls, and the part they have played in the development of mills that enabled the accomplishment of a system of rolling which had been the aim for years of manufacturers of wide-thin-flat products. The introduction of roller bearings to mills forced the advocates of the conventional bearing on the defensive and resulted in the more extensive use of forced grease lubricating systems for roll necks. Our Society's Annual Conventions for the past three years, have been noteworthy for the large variety of pressure lubricating devices there displayed and most of them developed for main roll lubrication and using a soft easily pumpable grease. Many of these installations have proven to be quite satisfactory and have furnished competition to roller bearing applications.

The advent of the non-metallic roll bearing using only water as a lubricant, and no oil or grease, marks the third step in the attack on the main roll bearing problem. The first widely used non-metallic material was lignum vitae which is a hard wood grown in semi-tropical countries. The second and probably the most interesting of all present materials used for this purpose is the textile or paper or other fibrous material impregnated with phenolic materials and sold by various manufacturers under trade names with which you are familiar. Mention of these bearings in this article shall class them as "Composition".

Lignum vitae paved the way for the use of these latter materials. Its earlier applications were mainly in small high speed mills, where it still has much use. In such mills, the application of grease to bronze and babbitt bearings is particularly difficult so that a water lubricated material, with a relatively low coefficient of friction and low first cost, found a ready reception. In one 10" Rod Mill of 17 Stands, the average power consumption during a three months period in 1929 showed 112 K.W. Hrs. per ton using all babbitt and bronze bearings and grease. In 1930, during the corresponding three months period and using lignum vitae, water lubricated, on all but the first four stands, the average power consumption was 85 K.W. Hrs. per ton. The starting load on lignum vitae was higher than on bronze and babbitt in the ratio of 3200 to 2800 K.W. This is probably due to the fact that a certain speed is required to cause the water to follow around between the neck and the bearing.

As a result, it became and still is the practice to swab the necks with a little waste oil at time of shutting down so as to facilitate starting and to keep the necks from rusting. The slowest speed on which lignum vitae or composition bearings have successfully operated on this mill is 163 feet per minute neck speed on No. 4 Stand though tests are now under way with composition bearings on neck speeds of 117 feet per minute and less. The highest neck speed in this mill is 2150 ft. per minute. The average life of bronze and babbitt bearings was 4300 tons as against the average on lignum vitae of 54,000 tons.

In a 12" Skelp Mill, an average of 13,200 tons was secured on lignum vitae. More recently "Composition" Bearings have been used in this latter mill and the only set that has worn out to date shows 49,000 tons of product.

Lignum vitae has also been used with success in a 60" Universal Plate Mill on 25" diameter necks. The neck speed of this mill varies from 327 to 654 feet per minute. In the larger mills, however, where higher bearing pressures are more apt to apply, the lack of uniformity of lignum vitae and its lower compressive strength as compared with "composition" bearings renders its use more limited.

Composition bearings, consisting of a shell of the bearing material from ½" to 1¼" thick which is used as a facing on a cast steel bearing, are continually widening their field of application from the smallest high speed mills to the largest plate mills. Compressive strengths of from 30,000 to 40,000 lbs. per sq. in. are claimed for these materials. It is to be noted that the same general restrictions probably apply to their use as is the case with lignum vitae, as far as speed is concerned. Though this may be overcome, it would appear that this low limit may be in the neighborhood of 100 ft. per minute neck speed. The power consumption with composition bearings seems to be still lower than is the case with lignum vitae. In one case, on test, the rolling power input on one stand showed about ½ the power required with lignum vitae as against bronze and babbitt and about ¼ the power required with composition as against bronze and babbitt. While sufficient tests have not been run to state definitely that these figures will hold, indications are strong that power consumption is very much less. This is further evidenced by the highly polished mercury like surface which roll necks take after running on either lignum vitae or composition bearings.

In a finishing stand of a 21" Continuous Mill, Composition Bearings running at 468 feet per minute showed only 1/16" wear in the shell after 68,800 tons though the composition thrust collars were worn out and had to be renewed. There appears to be no reason why properly designed composition bearings in thrust should not show equally proportionate results over bronze and babbitt.

These bearings apparently operate equally satis-

*Discussion of Mr. Coffin's paper will appear in the May issue.

factorily on either fresh or salt water (by salt is meant bay water of 450 gr. salt per gallon). It has not been the general practice to groove lignum vitae or composition bearings though some manufacturers recommend it. It would be interesting to have some conclusive information on this subject.

Encouraging the Uses For Steel with the Application of the Tool Called Electric Welding

During the past twenty years the electrical industry has been endeavoring to persuade the Steel Industry to adopt Electric Welding as a manufacturing tool to fabricate Steel products for universal uses.

The Steel Industry responded to some extent, mostly however, from the maintenance of equipment point of view.

The Steel Industry through centralized welding departments have saved millions of dollars each year in normal operation, but so far no general line of action has taken place, in developing markets for welded steel products.

Taking recent welding developments into consideration, the Steel Industry will be able to absorb within themselves one hundred to two hundred thousand tons of welded steel products each year. Government statistics report for one year an expenditure of approximately $700,000,000 for castings. It is claimed by responsible authorities that at least 60% of this huge total could be diverted to welded steel products.

It would seem from the figures quoted that the Steel Industry could with profit, establish a general welding research bureau, whose duties and activities should embrace the development of welded steel products.

This general welding research bureau, should be organized and set up on both technical and commercial lines, the technical division to study manufacturing welding practices and their developments and the commercial division to find new outlets, new markets and new uses for welded steel products.

It might be well for the distribution departments of the Steel Industry and the manufacturers of welding equipment to arrange a conference, whereby a preliminary study of the problems of Welded Steel products and their distribution could be discussed, which should be of mutual advantage.

The Association of Iron & Steel Electrical Engineers as sponsors of the New Uses for Steel Campaign would be willing to undertake the responsibilities for a conference of this nature. There is no question but that a meeting of this type would promote favorable economic results and widen the distribution of Steel.

Employees' Suggestion Plans

By W. H. BURR
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Presented before the Philadelphia District Section of the A. I. & S. E. E., April, 1933.

Modern Business Success depends to a large degree upon the extent to which profitable suggestions are procured, developed and applied. That statement which appeared in a bulletin on Employees' Suggestion systems, published by the Service Bureau of Metropolitan Life Insurance Company deserves more than passing consideration. In fact most of the large manufacturing industries today have some form of Employees' Suggestion Plan. They may differ in some details but the same basic idea of drawing on the practical experience and specialized knowledge of individual employees is back of them all.

This plan of paying a workman for his ideas is one of the things which has resulted in building up the present relation between the employer and employees. It has helped the Management to come in closer contact with the workmen and the workmen to realize that the Management recognizes the ability of the individual employees. The idea is not a new one. For a time an erroneous impression prevailed among workmen the whole idea being considered by some as a huge joke.

Suggestion plans may be classified according to the period during which ideas may be turned in.

These are Continuous, Contest and a Combination of both. Continuous as the name implies is one which permits employees to turn in Suggestions at any time.

The Contest plan specifies a limited time during which the suggestion system is operative.

The third simply combines these two. Most systems are of the Continuous plan.

The scope and nature of suggestions seems to be well defined in the General Electric Booklet on suggestion plans. "The basis of a suggestion should be a new idea or a new application of an old idea."

The rewards vary greatly with the different companies, but cash awards are the most generally used.

The administrative organization is rarely ever the same. General policies are, in most cases, determined by the Board of Directors or by major executive officers, but the administration of the plan is usually entrusted to a committee appointed by the Management. The personnel of the committee varies widely due to the nature of the business and the ideas of those in authority.

The system in use at Lukens can be outlined briefly as follows:

Suggestions may cover improvements in equipment which will reduce repairs, delays, power, labor, accidents, or increase the output or efficiency of operations.

All employees except department superintendents or their assistants are eligible for awards.

All suggestions are acknowledged by the President or through his office.

Suggestion boxes so marked are located at accessible points in the works. Once a week the suggestions are collected and turned over to the Suggestion Committee.

Committee consists of three members; the chairman chosen by the Management and two members selected by the chairman and approved by the Management.

Once a month Committee holds a meeting and acts on suggestions received.

In many cases the suggestions are turned over to the heads of the department in which suggestion is applicable for comments. Advantage is taken of the information in the office of Chief Engineer, and in fact any one in the organization who may be qualified to deal with the suggestion.

The Committee decides on the merits of the suggestion after obtaining what they consider adequate information and the awards in most cases are based on the savings to be effected.

Rewards which are recommended in the plant range from two dollars to twenty-five dollars.

When five suggestions from the same author have been accepted and paid for, the employee is given a bonus of 20% of total amount received for those five suggestions. One employee has turned in forty suggestions and received a bonus on two occasions indicating that ten of his suggestions have been accepted.

The average award for suggestions accepted is between eight and nine dollars.

Some 567 suggestions have been received and 185 accepted.

One of the most essential things in a suggestion system is to make sure everything possible is done so that the author of the suggestion is satisfied that his suggestion has been given careful consideration, and he must be satisfied also with the explanation why it was not accepted if Committee fails to make an award.

Some of the suggestions which have been received at Lukens are, I believe, applicable in other plants and with this thought in mind I will outline some of them.

One of the first suggestions received was that steel plates be placed around the piers in the Open Hearth and Plate Mills, which were filled with concrete. Previous to this time the brickwork or concrete at the base of columns was damaged in handling ingots, moulds and plates and had to be renewed frequently.

In our Open Hearth each furnace was originally equipped with a spout hoist to handle tapping spouts back of furnaces. Due to the heat while tapping and the position when not in use the maintenance on these hoists was extremely high. As a result of a suggestion we now use a counter balanced beam. The main hoist on a pit crane is hooked to the center of the beam. The auxiliary hoist is hooked to the counter weight on one end and the other end of the beam is hooked to the spout. With this arrangement the crane operator handles the spout with no trouble whatever.

In the mills as plates are finished they pass over scales before being shipped. No end of trouble resulted from hooks on cranes catching on the tables located on the scales, with the result that the maintenance cost was very high on these scales. Plates were welded around the sides of these scale tables so the hooks could not catch on them.

In turning plates around on the table back of 84" Roughing Mill advantage is taken of the double motor drive. Alternate rollers on table are driven from one side and the remaining rollers by a motor on the opposite side of table. Normally both motors are controlled with one master switch. To turn the plate the operator pushes the button in the handle of the master which closes two contacts fastened to a rod on the end of the button. This reverses the direction of one of the driving motors. A spring return on the button gives normal direction of motor when button is released. This idea helped to reduce the number of operators on this plate mill.

In an open hearth it is necessary to make repairs on the roofs on the furnaces. This is hot and dangerous work. On the steel buck stays on the furnaces, plates are now welded forming pockets into which pieces of flat steel are placed when repairs are being made. These form a very strong and rigid support for the platform on which the bricklayers stand while making repairs to the furnaces.

Time will not permit me to dwell longer on these suggestions. New ideas have been responsible in the past few years for the vast improvement in living conditions among the people of this nation and new ideas are going to play a most important part in the restoration of normal economic conditions.

The purpose of this paper will have been accomplished if I succeed in getting you to think seriously enough of the benefits derived from such a suggestion system to see that a similar plan is made operative in the plant in which you are employed.

HELP

YOUR INDUSTRY

△

Send in your

Suggestions

for

New Uses for Steel

ITEMS OF INTEREST

PERSONNEL CHANGES

▲

The Reliance Electric & Engineering Co., Cleveland, announces the appointment of W. W. Spanagel as District Manager for the Cleveland territory. Mr. Spanagel has been acting in this capacity for several months.

▲

The Harnischfeger Corporation, Milwaukee, has announced the appointment of Florandin Equipment Company, 40 West 40th Street, New York, as its welder representative in the metropolitan district of New York and northern New Jersey.

▲

Effective April 1st Harry J. Fisher establishes himself and associates as Distributor in Ohio for The Clark Controller Company of Cleveland.

Until recently, Mr. Fisher was Sales Manager of the Aetna Standard Engineering Company of Youngstown, Ohio and prior to that, for several years, handled the sales of Reliance Motors in Steel Mills and general industrial plants.

Motor control will not be a new experiment for Harry Fisher as many of his old friends will recall his success in selling originated with this class of apparatus.

Mr. Fisher will have his headquarters in Cleveland.

▲

At a recent meeting of the Board of Directors of the Farrel-Birmingham Co., Inc., Ansonia, Conn., the following officers were elected:

Franklin Farrel, Jr., Chairman of the Board of Directors; Nelson W. Pickering, President; David R. Bowen, Vice President; Carl Hitchcock, Vice President; Franklin R. Hoadley, Vice President; Armin G. Kessler, Vice President; Frederick M. Drew, Jr., Treasurer; Laurie K. Blackman, Assistant Treasurer; George C. Bryant, Secretary, and William B. Marvin, Assistant Secretary.

Alton Farrel, who has been connected with the company for thirty years and has been Treasurer for twenty years, resigned as Treasurer and Director of the company, because of illness. Frederick M. Drew, Jr. was elected Treasurer and Director in his place.

WITH THE MANUFACTURERS

▲

The Electric Controller & Manufacturing Company, 2696 East 79th St., Cleveland, Ohio, is marketing a new Type A Safety Switch.

Although liberally designed for the severe duty encountered in mill service, these safety switches are of extremely compact construction; the overall dimensions are small, nothing projects beyond the width of the box and the cover swings vertically, all of which permits minimum mounting space. Furthermore, these switches are enclosed in boxes having a handsome finish, which makes them equally desirable for installations where good looking appearance is important.

These switches are quick make and quick break—double break, semi-floating V-Blades (movable contacts) engage and open rapidly; they can not be partially opened or partially closed. Steel Back-Up Springs on the V-Stationary-Contacts guarantee full contact under heavy pressures; that is, heavy pressure is maintained along the full width of the contacts.

The fuse door of these switches is interlocked with the operating handle so that raising the door trips the switch and the fuses can not be reached except when the switch is open.

The switch mechanism is assembled on a single base which is held in the box by four screws. This permits easy removal of the entire mechanism as a unit for inspection, replacement of parts, or substitution of a new switch. Likewise, although the gutter space is large, the switch can be removed as a unit, if desired, to allow all the space in the box for pulling in wires; that is, remove the four screws to take out the complete switch unit, mount box in position, attach conduit, pull in wires, then remount switch in box, fasten cover on with two screws and attach operating handle.

Because of the narrow width of these boxes, the operating handle in front and the fact that the cover swings vertically requiring no clearance on either side for opening the door, these switches can be mounted in wall recesses, along the wall without interfering with pipes on either side or arranged in groups without space between.

These safety switches are convertible from larger to smaller sizes by simply changing fuse clips and moving fuse block to the proper threaded holes supplied in all boxes .

▲

"VYSTIPE" FUSE CLAMPS

The Trumbull Electric Mfg. Co., Plainville, Conn. have announced the addition of "Vystipe" (pronounced vise-type) fuse clamps to their 30 ampere 230 volt fusible "R. B." switches, which now makes the entire line of "R. B." switches available with "Vystipe" clamps 30-800 amperes inclusive.

Thorough tests have shown that this pressure type of clamp by compelling proper fuse alignment and contact, permanently reduces heating 80% over properly contacted ordinary ferrule fuse clamps 30-60 amp., and an average of 28% over properly contacted knife blade fuse terminals 100-800 amperes, thereby preventing premature "blowing" of fuses.

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The Blaw-Knox Company of Pittsburgh, Pennsylvania, has added to their line of steam power equipment a Desuperheater based on an entirely new principle, which embraces in one piece of apparatus, complete desuperheating with steam purification. While the design is distinctly new in desuperheating, the main parts have been amply proven in standard equipment over a long period of time. Essentially the Blaw-Knox Desuperheater consists of a Blaw-Knox Contactor combined with a Tracyfier (steam purifier) and equipped with a standard make of boiler feed water regulator.

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WESTINGHOUSE TO ELECTRIFY REVOLUTIONARY STEEL MILL

A revolutionary method of making steel will be employed by the Rotary Electric Steel Company who recently awarded an order for the complete electrification of their new plant near Detroit, Michi-

gan, to the Westinghouse Electric and Manufacturing Company. The order totals $155,000.

Every electrical item for the new mill from the powerful motor drive down to the electric lights is included in the order. Among the more important items are 56 electric motors ranging from three to 800 horsepower, a 10,000 kva electric furnace transformer, control apparatus for the electric furnace and casting machines, and all other electric equipment.

The steel is made in an electric furnace and then cast by a new centrifugal process. Instead of casting an ingot in a stationary mold the molten metal is poured into a large circular mold which is then rotated at high speed. When sufficiently cool, the casting, in the form of a huge ring, is cut into billets and rolled in the conventional manner.

Centrifugal force acting upon the individual molecules of steel seems to give the metal exceptional qualities. With the drills made of ordinary steel a certain machine shop was able to drill only 11 holes in a given thickness of steel plate. With drills made of steel cast by the centrifugal process, the shop was able to drill 41 holes before the cutting edge wore off the tool. Tests are now being made to determine whether the new steel can be used for the brake lining of automobiles.

An unusual feature of the new Rotary Electric Steel plant is that the equipment investment is only $20 per ton of completed steel whereas the investment of conventional plants averages about $100 per ton of output.

The Rotary Company plans to buy their raw materials—scrap iron and steel—from places nearby and to sell their products in nearby places. By reducing transportation costs on the raw materials and finished product to a minimum, the Company hopes to be able to outdistance the competition of steel manufacturers conventional methods.

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A NEW LINE OF G. E. CONTROLLERS FOR SYNCHRONOUS MOTORS

All standard lines of General Electric synchronous motor control have been superseded by new lines incorporating new and important features. Included in this control equipment are relays for automatically applying and removing field excitation and for protecting the stator and amortisseur windings under all operating conditions.

For automatically applying field excitation when the motor reaches a predetermined speed near synchronism, a new relay known as the slip-frequency field-application relay is provided. The coil of this relay is connected across a section of the field discharge resistor with a half-wave copper oxide rectifier in series with it. During the starting period, induced field current of slip-frequency flows through the discharge resistor so that half-waves of slip-frequency current flow through the relay coil causing the relay to pick up and open its normally closed contacts. This relay has a short time delay drop-out which holds the contacts open during the period of acceleration. When the motor reaches a predetermined speed near synchronism, the time interval between half-waves of current is sufficient to allow the relay to drop out and apply field. By a simple adjustment of the relay, its time setting can be varied so that it will apply field at any predetermined speed from 92 to 99 per cent of synchronous speed.

In addition to a means for automatically applying field excitation near synchronism, the new General Electric motor controllers are provided with a power-factor field-removal relay which automatically removes field excititation when the motor drops out of synchronism. The operation of this relay depends upon the power factor of the line current drawn by the synchronous motor. The relay is designed so that it remains closed if the motor power factor is leading, or unity, or not less than 60 per cent lagging. If the motor power factor, however, becomes less than 60 per cent lagging, even for a short time, the relay operates to open its contacts and remove field excitation. Hence, this relay will remove field only when the motor pulls out of step, and under such conditions it operates to remove field immediately, that is, during the first slip cycle out of synchronism.

These General Electric synchronous motor controllers are also provided with a two-element temperature relay for protecting the stator windings and, in addition, a temperature squirrel-cage protective relay is included to protect the amortisseur windings under all operating conditions. A new Telechron motor-operated timing relay is used to initate the transfer from "starting" to "running" connections on reduced volage and "part-winding" controllers.

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Allis-Chalmers Manufacturing Co., Milwaukee, Wis., are distributing their new four page bulletin 1164 on Motor Reduction Units. Copy of this bulletin may be secured by writing above company.

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NEW BOOKS

Cutting costs by redesigning is the theme of new book published recently. "Designing for Arc Welding" is the title of the book, which contains prize winning papers submitted in the $17,500 Second Lincoln Prize Competition. The published papers are those judged the best from some 400 submitted in the competition and include the work of foremost engineers in the United States and abroad.

The editor is A. F. Davis, Vice President of the Lincoln Electric Company.

The book is bound in cloth-covered boards and published by The Lincoln Electric Company, Cleveland, Ohio and is sold for $2.50.

OBITUARIES

Charles Edward Eveleth, 57, vice president of the General Electric Company, died at Schenectady, March 25 following an illness of several months.

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Mr. G. C. Otto, who had charge of the distribution of electrical products for the C. A. Turner Company, Pittsburgh, Pa., died suddenly on April 1. Mr. Otto was widely known in the Pittsburgh district having contacted the Steel Industry and allied Industrials for the past 20 years.